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GB 1528581
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(54) Determining the location at which a force is applied to a member

(57) The location (in one dimension) at which a force (Fa) is applied to a member (40) is determined using force sensors (41, 43, 44, 47, 51) and (42, 43, 45, 48, 52) which produce electrical signals representing the component of the force thereat, and an arrangement (53 to 67) which calculates the location at which the force is applied from the electrical signals (Fig. 5). The determination of the location in two dimensions of a force applied to a member such as a chess board or touchplate associated with a TV screen is described.

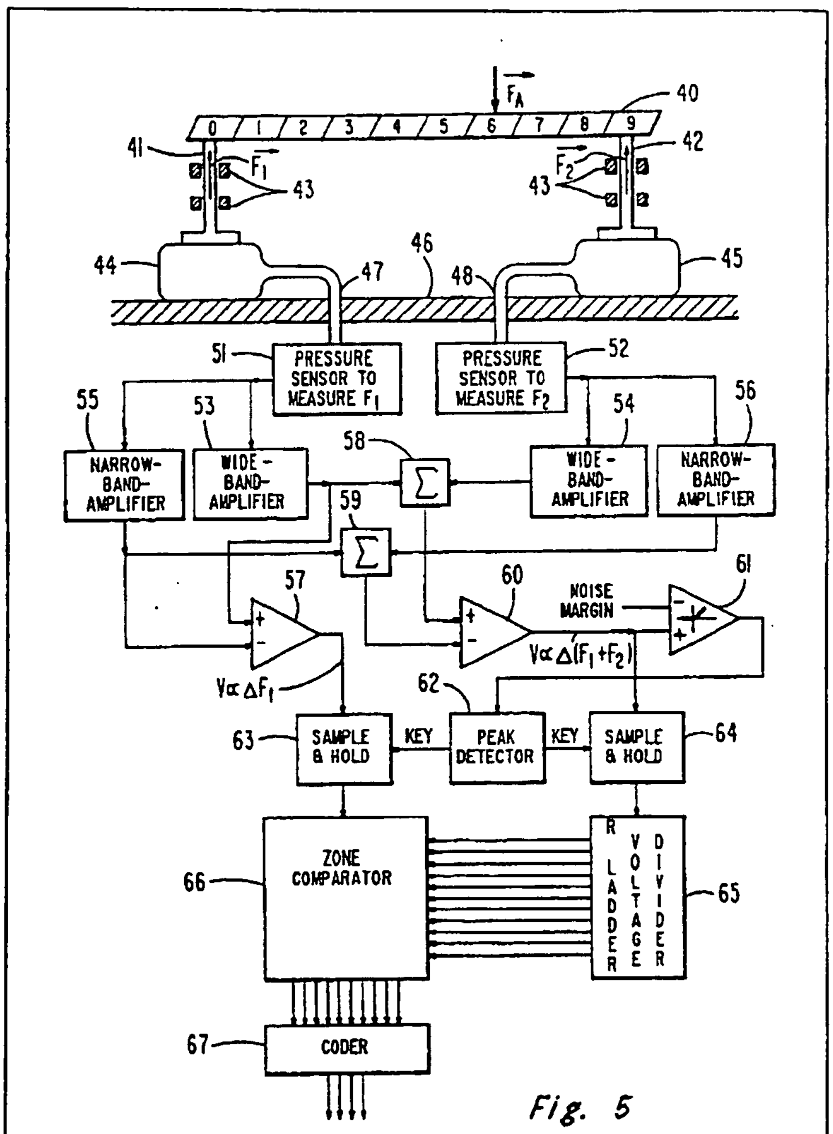

Fig. 5

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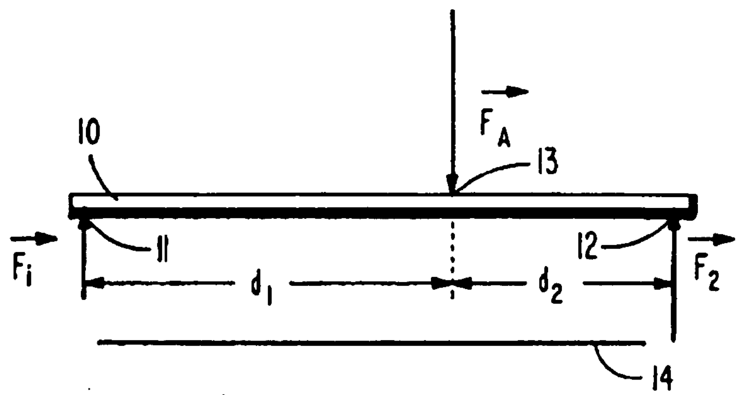


Fig. 1

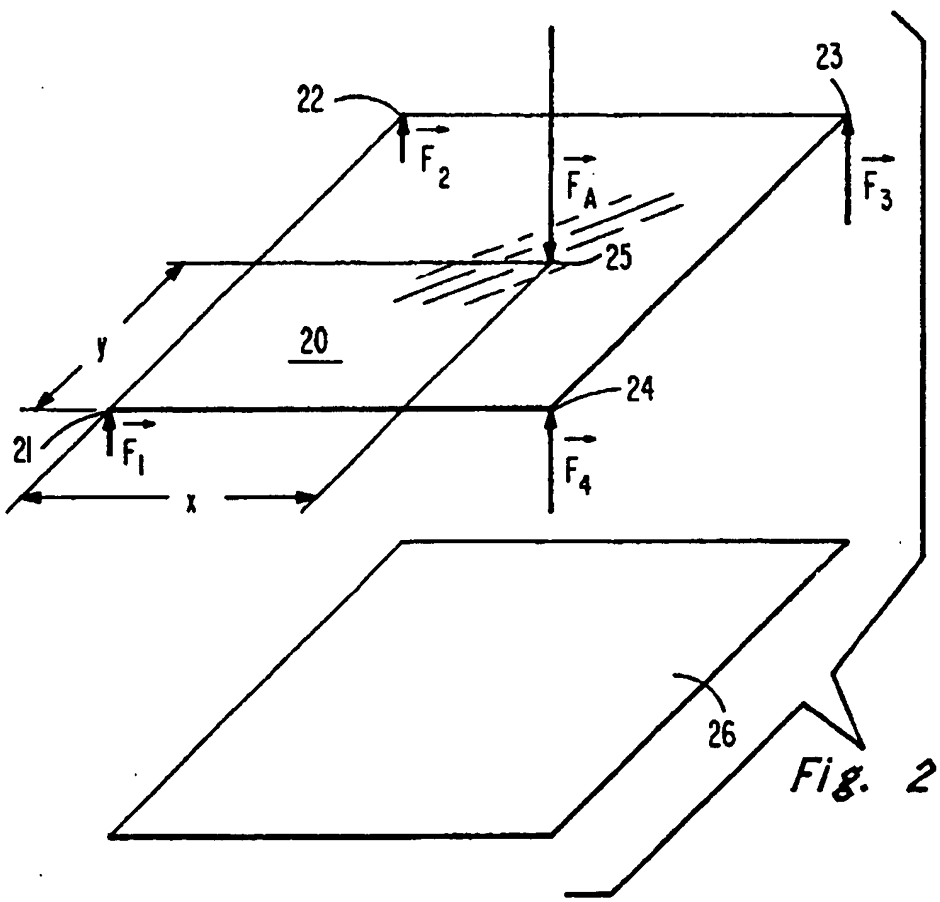


Fig. 2

Fig. 3

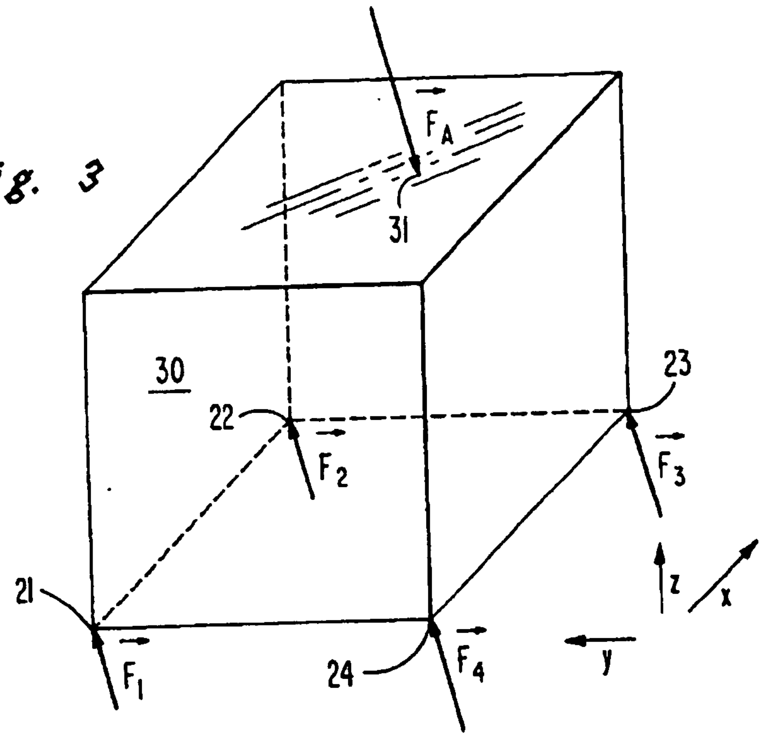
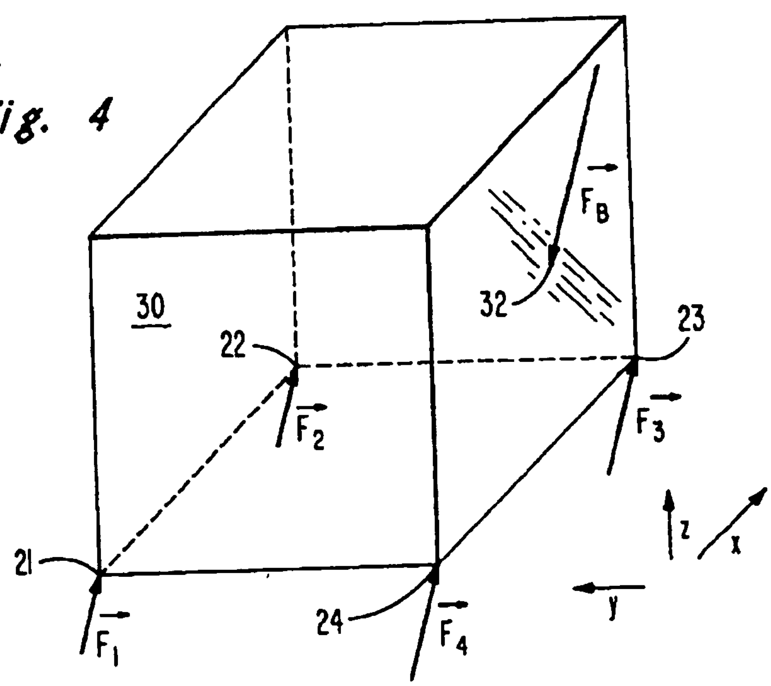

F_A
31
30
22
F_2
23
F_3
z
x
21
F_1
24
F_4
y

Fig. 4


F_B
30
32
23
22
F_2
F_3
z
x
21
y
24
F_1
F_4

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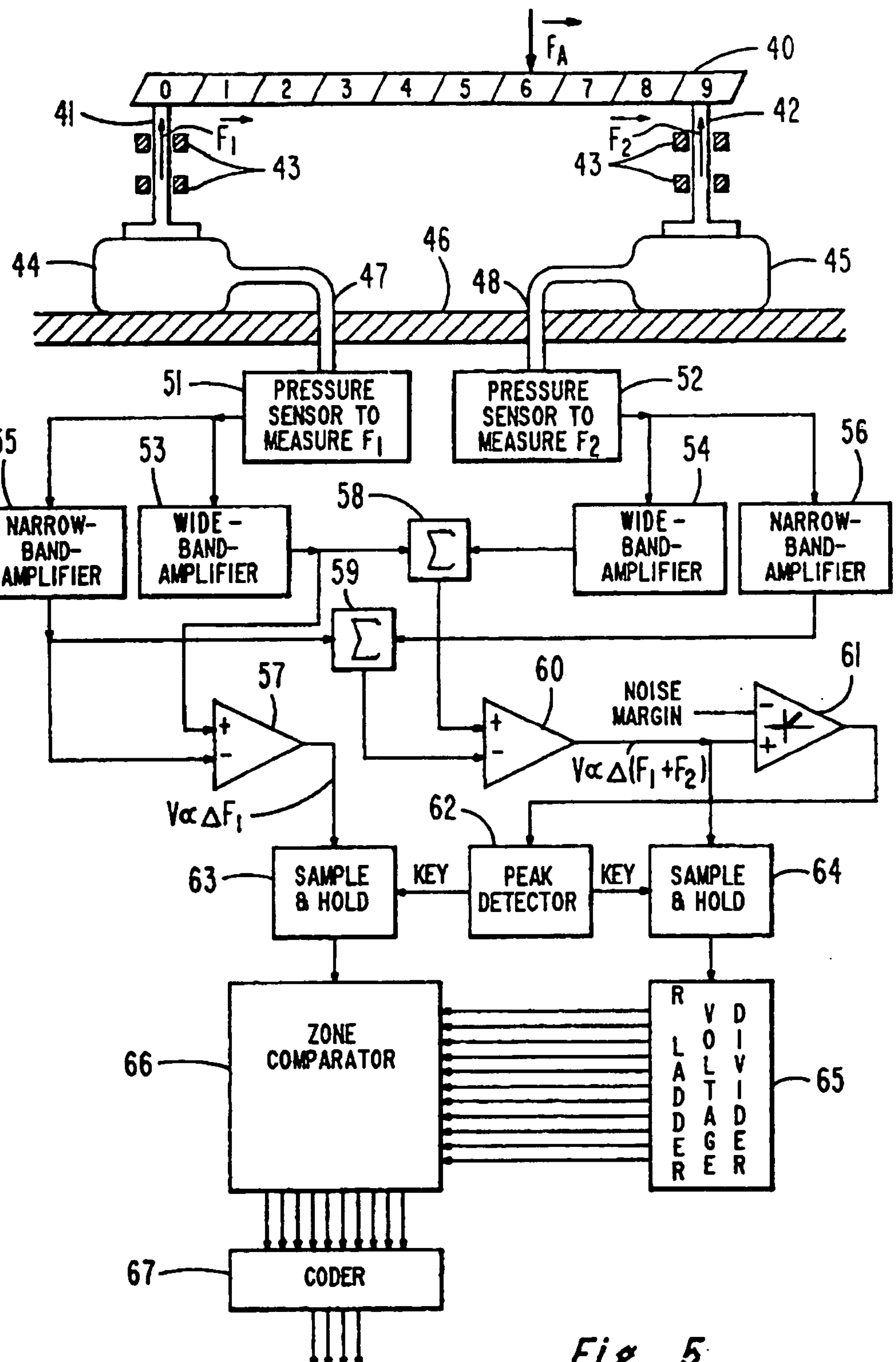


Fig. 5

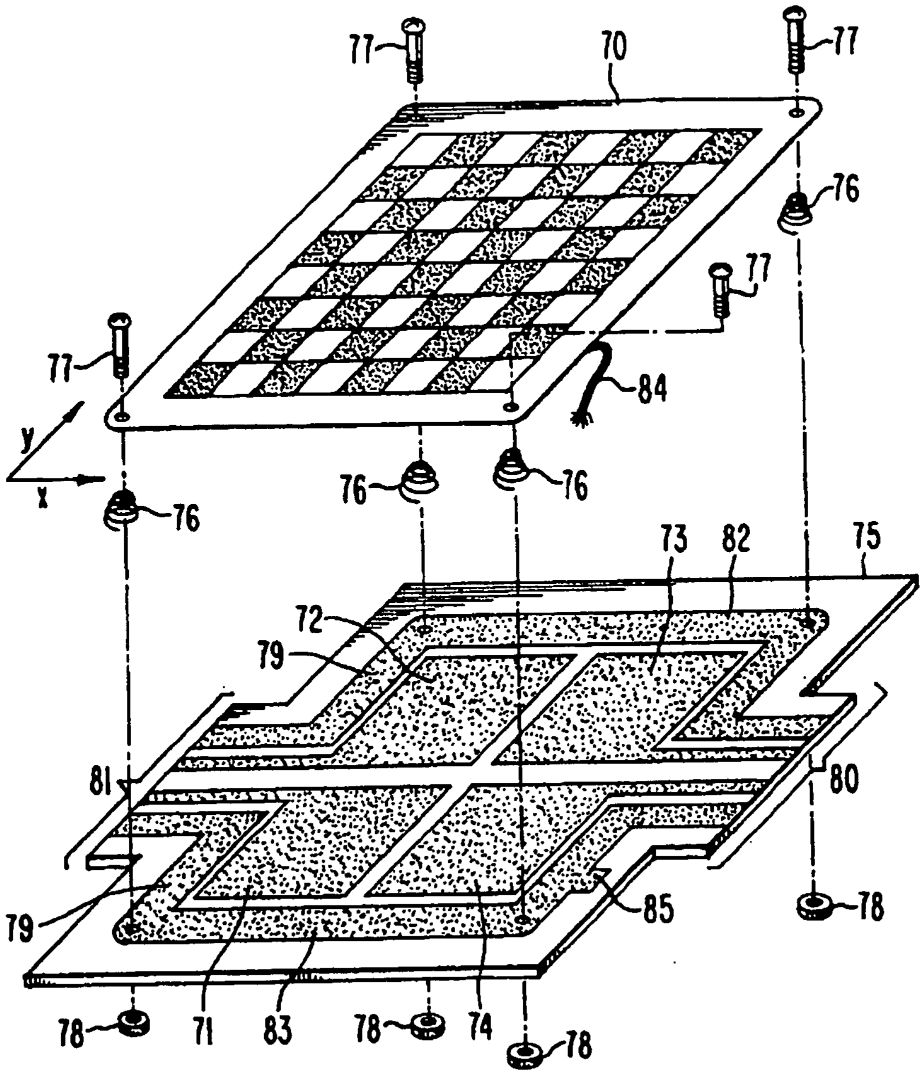
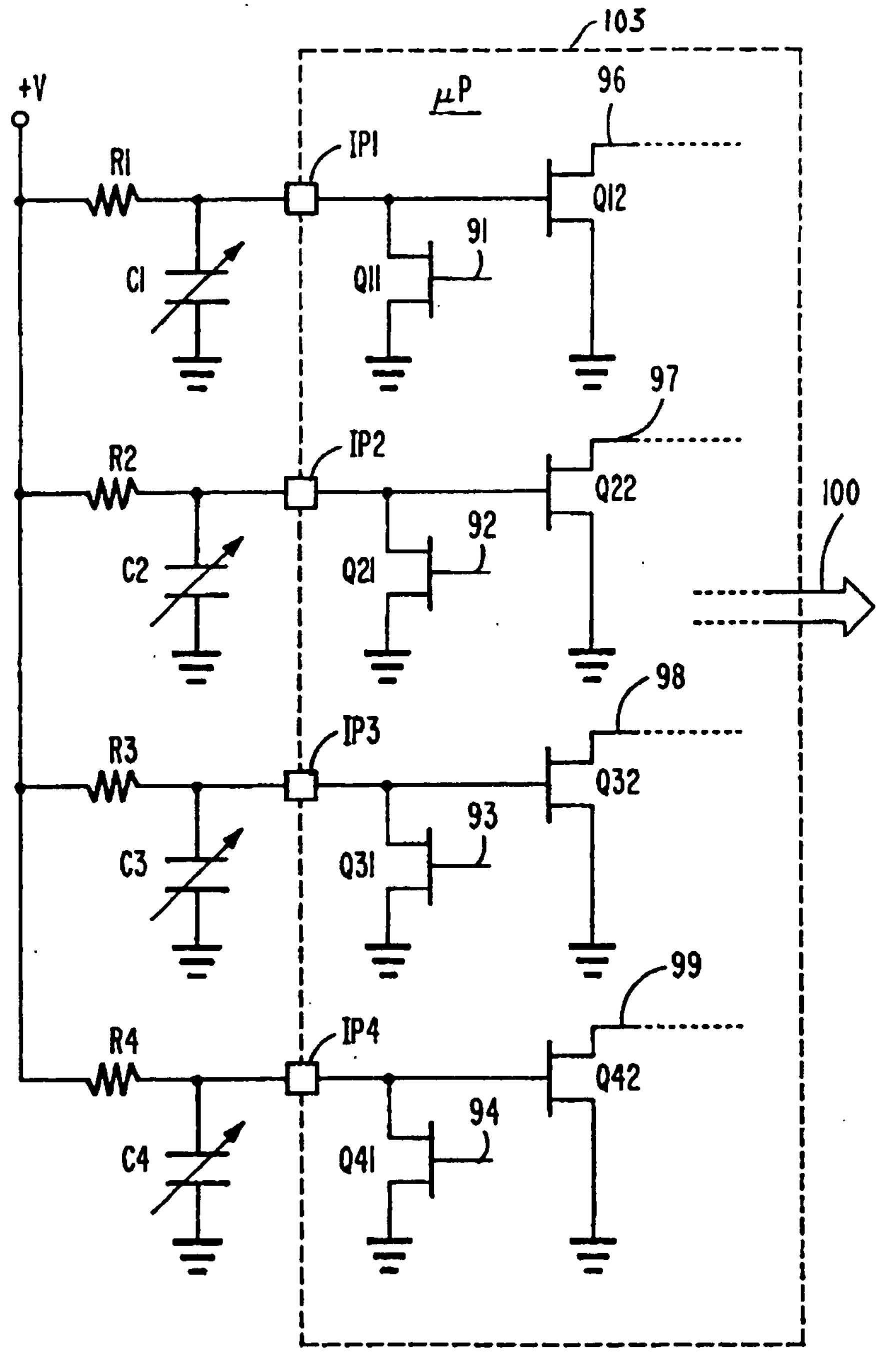

77
77
70
76
77
77
84
y
x
76
76
76
73
82
75
72
79
81
80
79
85
78
78
71
83
78
74
78

Fig. 6

Elke



103
μP
+V
R1
R2
R3
R4
C1
C2
C3
C4
IP1
IP2
IP3
IP4
Q11
Q12
Q21
Q22
Q31
Q32
Q41
Q42
91
92
93
94
96
97
98
99
100

Fig. 7

MAIN PROGRAM FLOW

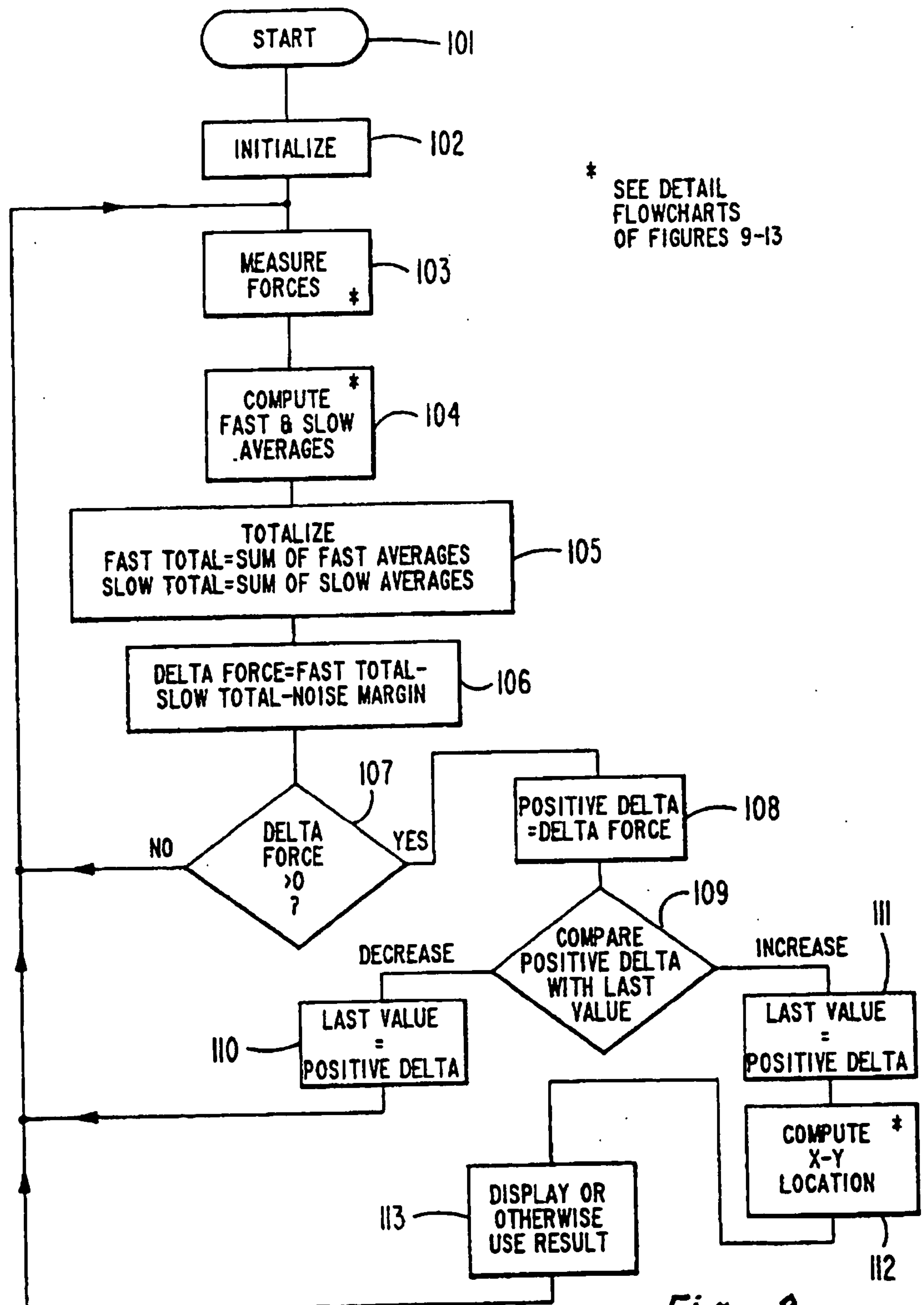


Fig. 8

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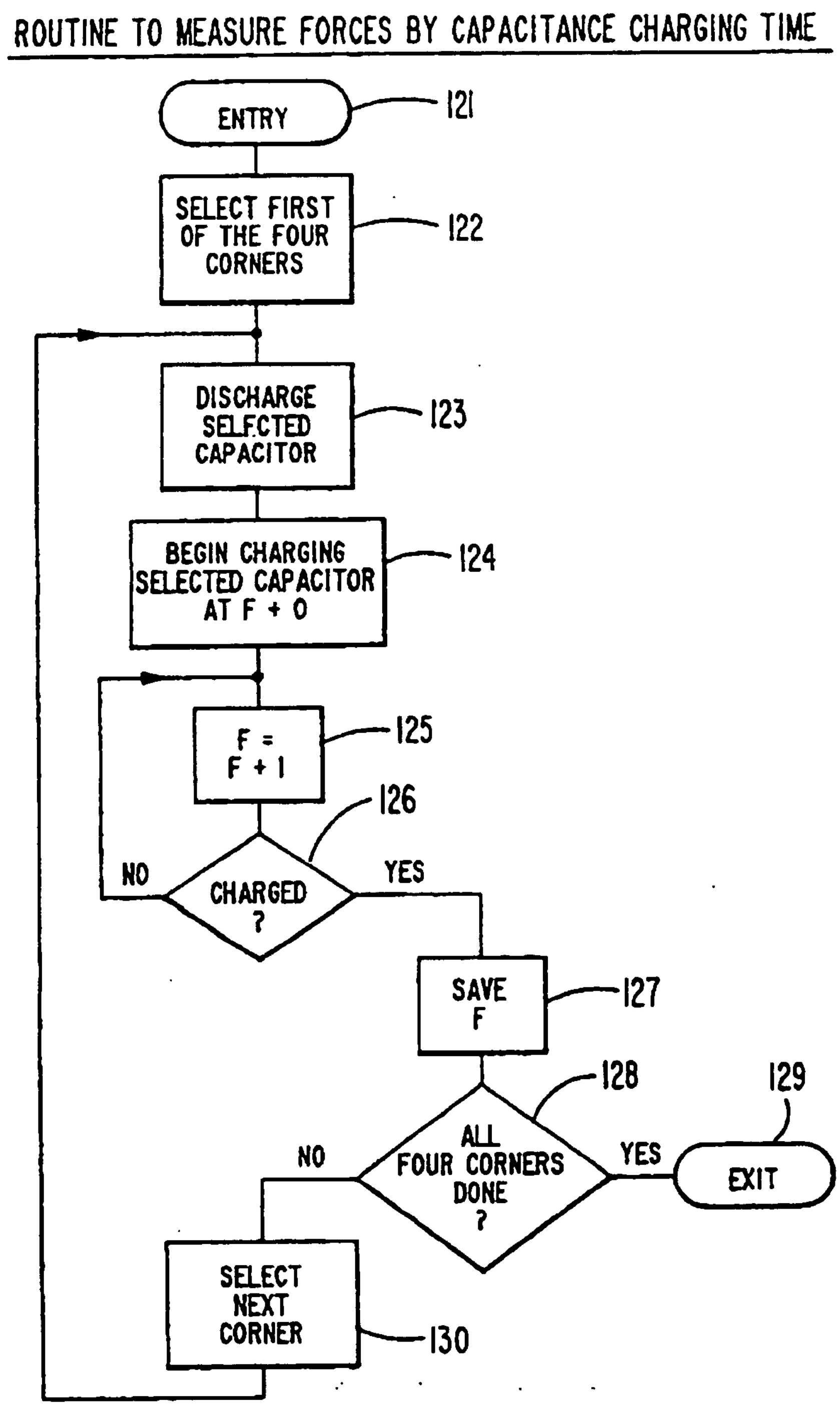

Fig. 9

ROUTINE TO COMPUTE LONG-TERM (SLOW) AVERAGES AND SHORT-TERM (FAST) AVERAGES OF EACH OF THE MEASURED FORCES

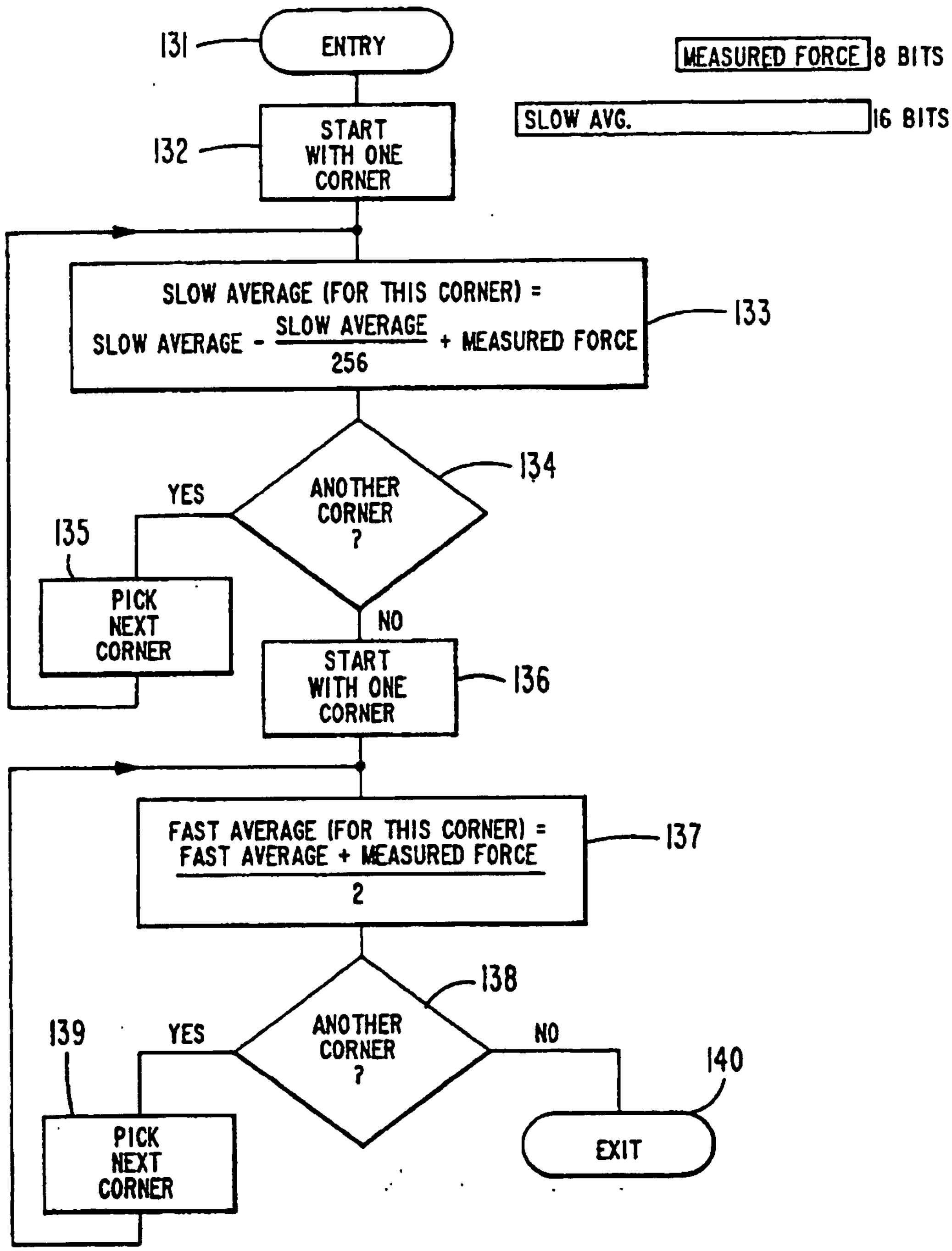

Fig. 10

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ROUTINE TO COMPUTE X-Y LOCATION OF POINT OF APPLICATION OF FORCE ON TOUCHPLATE

Enter with SLOW AVERAGES SBL,SBR,STL & STR of measured differential forces for bottom left,bottom right,top left and top right quadrants,respectively, and with corresponding FAST AVERAGES FBL,FBR,FTL & FTR.

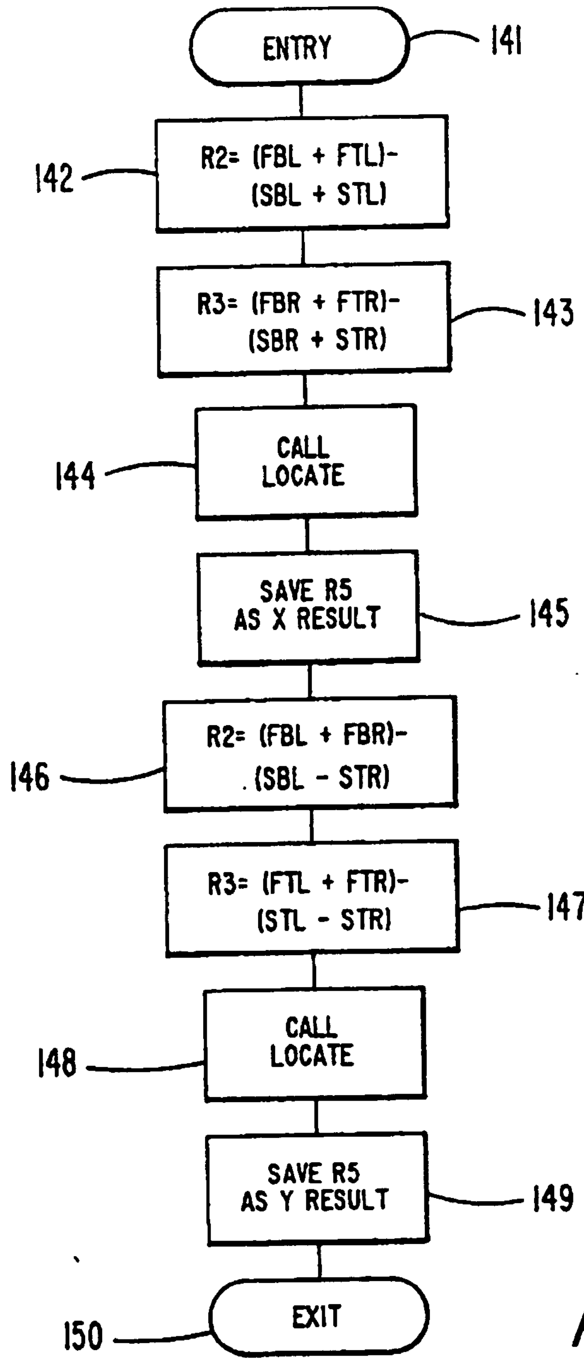


Fig. 11

SUBROUTINE TO CALCULATE LOCATION OF APPLIED FORCE

CALL WITH: R2= Σ LEFT OR BOTTOM DIFFERENTIAL FORCES
R3= Σ RIGHT OR TOP DIFFERENTIAL FORCES
RETURN WITH: R5= x OR y LOCATION OF FORCE AS BINARY FRACTION

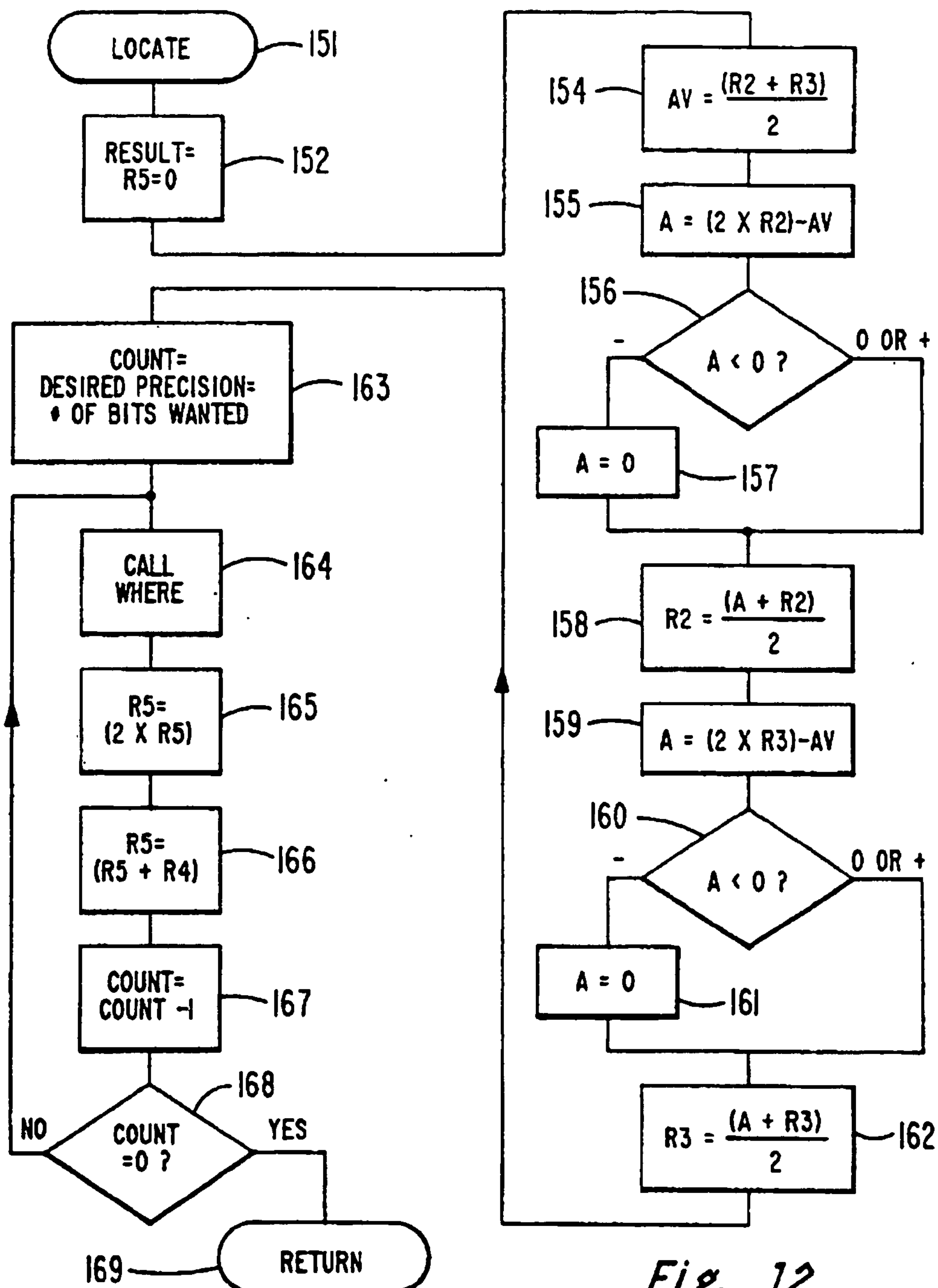


Fig. 12

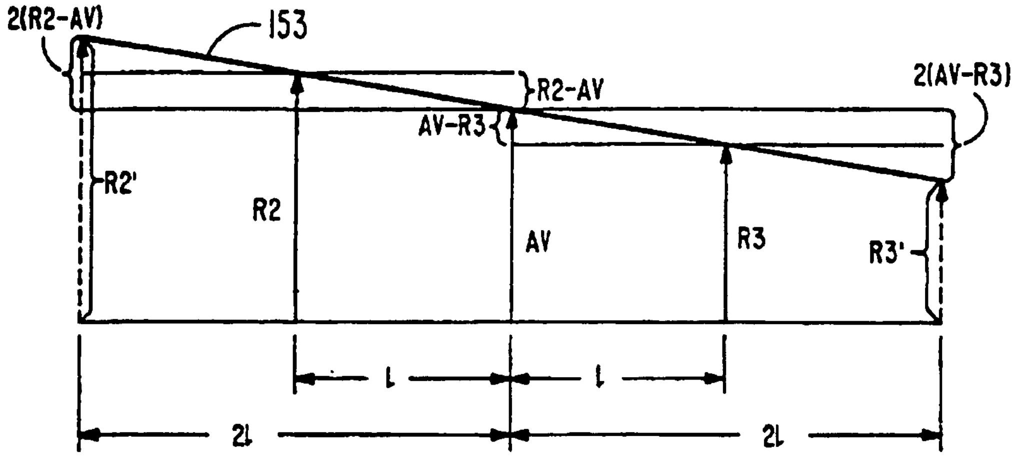


Fig. 13

SUBROUTINE TO CALCULATE EACH BIT OF THE LOCATION OF APPLIED FORCE

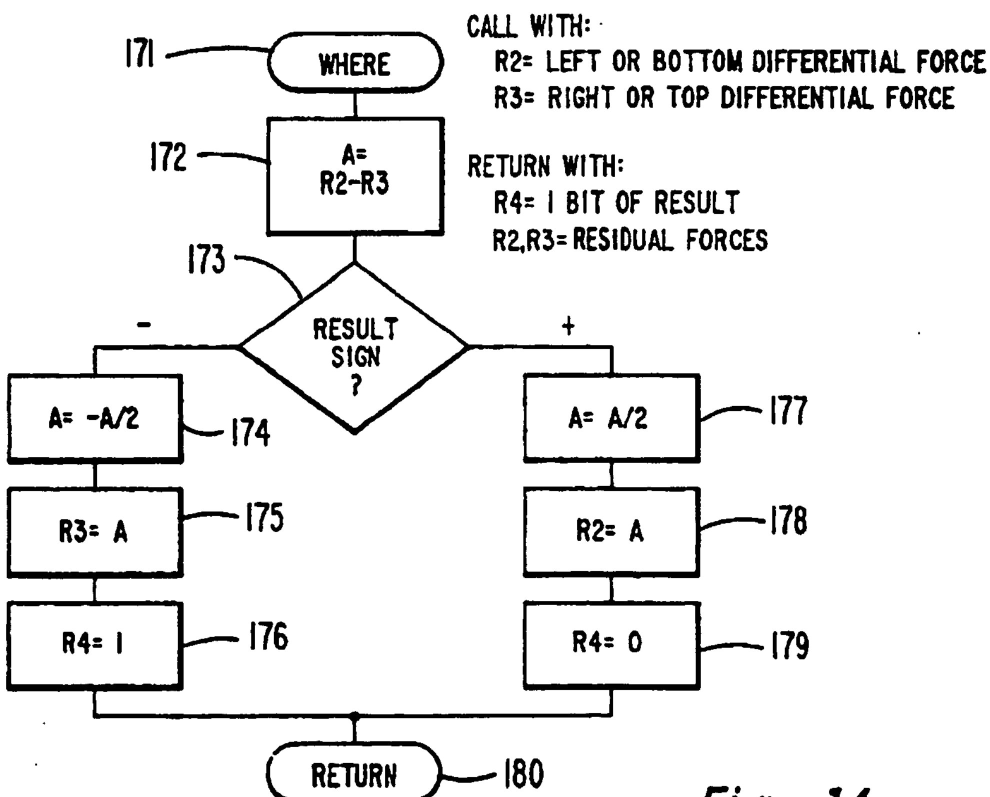
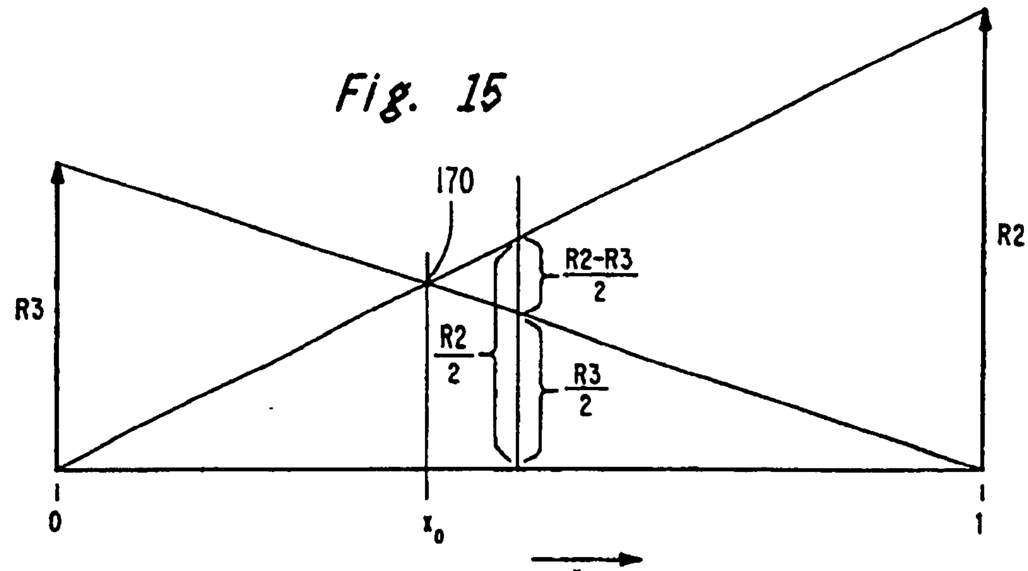


Fig. 14

Fig. 15


170
R2
R3
R2-R3
2
R2
2
R3
2
0
x_0
1
x

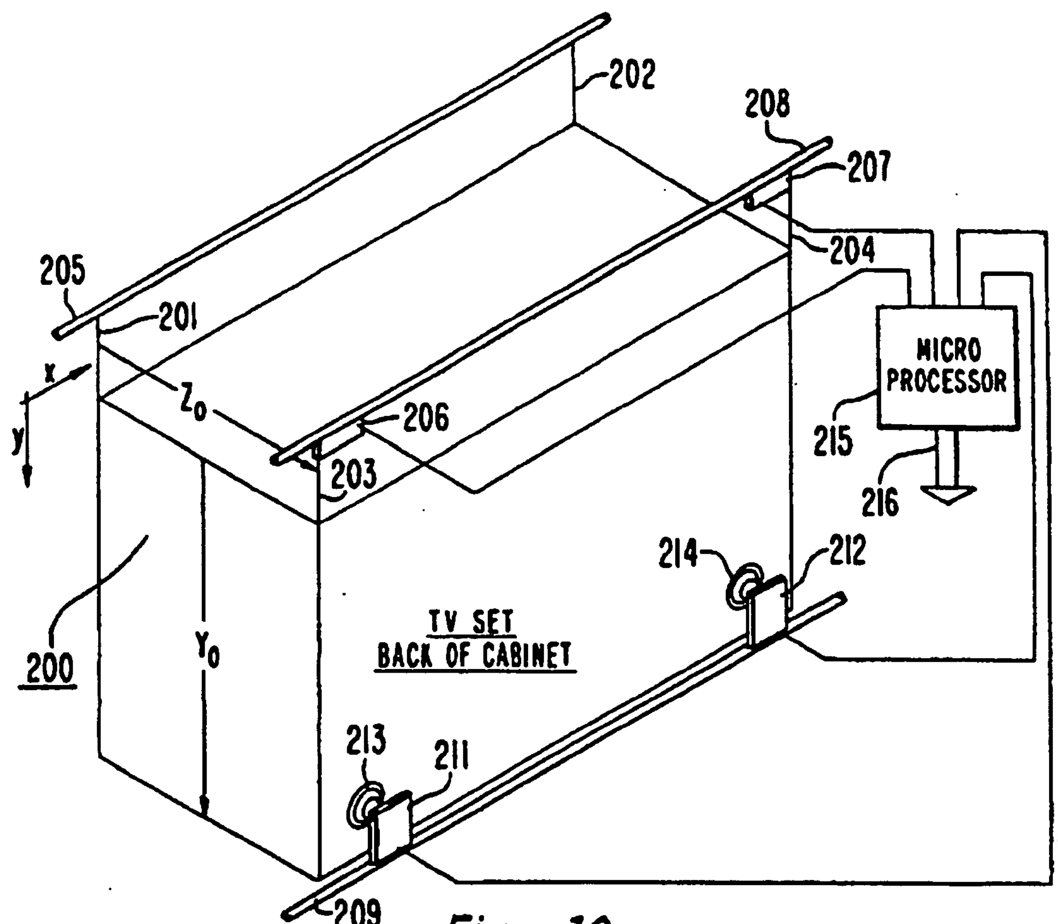

202
208
207
204
205
201
MICRO PROCESSOR
x
Z_0
206
y
215
203
216
214
212
TV SET
BACK OF CABINET
200
Y_0
213
211
209

Fig. 16

SPECIFICATION

Determining the location at which a force is applied to a member

The present invention relates to determining the location at which a force is applied to a member.

An illustrative application of the invention is to mechanically actuated general input controls, touchbars, touchplates and the like, where the point of touching determines the input to be supplied to an electronic system.

In the prior art the determination of the point of touching of a surface has been made by sensing capacitance change or hum field pick-up on individual capacitors arrayed on the surface. The reflection of sound waves or the interruption of crisscrossing infra-red beams at a touch point on a surface have also been used in touchplate sensors. Such a touchbar or touchplate is likely to be actuated erroneously by the user or his clothing accidentally brushing or nearly brushing its surface. Consequently, it is very desirable from a practical viewpoint to have a system where a threshold force can be defined so that lighter touch of the surface is ignored by the system. This argues for a touchbar or touchplate that responds to mechanical force. A keyboard using elastically deformable membranes disposed on the touchbar or touchplate is the solution for this problem employed up to his time. Keyboards which offer reliable and accurate inputs out many cycles of operation are difficult to make and require a substantial number of interface connections; consequently they tend to be undesirably expensive.

The present invention is used for determining the identity of a selected location, from a multiplicity of locations on a surface of a mechanical member, such as a touchbar or touchplate. According to the invention, the location is selected by applying force to the location. Force-sensitive sensors, which are connected to the member, develop electric signals descriptive of the components of the applied force. The identity of the selected location, i.e., the location to which force is applied, then is calculated from the relative amplitudes of those electric signals.

In the drawing:

FIGURES 1 and 2 are diagrams useful in understanding how the points to which user force is applied to a touchbar and to a touchplate, respectively, can be calculated proceeding from the resolution of the force at the support points of these mechanical members;

FIGURES 3 and 4 are diagrams useful for understanding the calculation, of the touchpoint at top or side of a rectangular prism supported at its four lower corners;

FIGURE 5 is a schematic diagram, largely in block form, showing apparatus for providing output indications of the touchpoint along a touchbar, which apparatus embodies the invention;

FIGURE 6 is an exploded view of a chessboard apparatus with means providing capacitances variable responsive to player-applied force provided therewith in furtherance of the invention;

FIGURE 7 is a schematic diagram of the interface of the FIGURE 6 chessboard apparatus with the microprocessor used for calculating the point at which the player applies force to the chessboard;

FIGURES 8—12 and 14 are flow charts descriptive of such calculation;

FIGURES 13 and 15 are diagrams useful in understanding certain method steps in these flow charts; and

FIGURE 16 is a perspective view of the mounting of a television set, as it would be in a hutch cabinet, for actuating force sensors that calculate the point of user touch on the faceplate of the television set.

In FIGURE 1 the mechanical member to be considered is a touchbar 10 supported at support points 11 and 12. Touchbar 10 may have touchpoint locations indicated on its top surface. If touchbar 10 is made of transparent material an underlying display 14 (shown in profile) may be viewed through it, and touchpoint locations may be indicated in the display. Initially, for purposes of explaining the theory of the invention, it is assumed touchbar 10 has no component of weight in the downward direction on the paper. A user of the touchbar 10 is assumed to apply a downward force of $\vec{F}_A$ at a user-selected touchpoint 13 located distances d_1 and d_2 respectively from support points 11 and 12. F_A is resolved into two downward component forces (not shown) exerted against support points 11 and 12. The touchbar 10 is maintained in equilibrium positioning by the countervailing upward forces $\vec{F}_1$ and $\vec{F}_2$ applied through supporting points 11 and 12. That is, to forestall translation of the touchbar 10 the scalar amplitudes F_1 and F_2 of vector forces $\vec{F}_1$ and $\vec{F}_2$ relate to the scalar amplitude F_A of vector force $\vec{F}_A$ as follows:

$$F_1 + F_2 = F_A \qquad (1)$$

And to forestall rotation of the touchbar 10 about support point 11 the clockwise moment $F_A d_1$ as referred to that point has the following relationship to the anticlockwise moment as referred to that point.

$$F_A d_1 = F_6 (d_1 + d_2) \qquad (2)$$

That is, the total clockwise moments equals the total anticlockwise moment. Substituting from equation 1 into equation 2, equations 3 and 4 are obtained

$$(F_1+F_2)d_1 = F_2(d_1+d_2) \qquad (3)$$

$$\therefore d_1/(d_1+d_2) = F_2/(F_1+F_2) \qquad (4)$$

So one can determine the fraction of the distance between support points 11 and 12 at which touchpoint 13 is located, by computation based upon measurement of the forces support points 11 and 12 have to exert on the touchbar 10. That is, normalizing (d_1+d_2) to unity, equation 5 is obtained expressing the distance between support point 11 and touchpoint 13 as a fraction x of the distance from support point 11 to support point 12.

$$x = F_2/(F_1+F_2) \qquad (5)$$

In FIGURE 2 the mechanical member to be considered is a rectangular touchplate 20 with support points 21, 22, 23, and 24 at respective ones of its corners. The absence of support points in the central portion of the touchplate 20 is advantageous where the touchplate is transparent and overlays display 26 on which a variety of touchpoints are indicated for user selection. Initially for purposes of explaining the theoretical background to the invention, it is assumed touchplate 20 has no downward component of weight. A user of the touchplate 20 is assumed to apply a downward force of $\vec{F}_A$ at a user-selected touchpoint 25, which is resolved into downward forces (not shown) on support points 21, 22, 23 and 24 respectively converted by upward forces $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$ and $\vec{F}_4$ that maintain equilibrium of the touchplate 20. Translation is forestalled by scalar amplitudes F_1, F_2, F_3 and F_4 of these upward forces summing to equal the scalar amplitude F_A of the user-applied force.

$$F_1 + F_2 + F_3 + F_4 = F_A \qquad (6)$$

Presume an x, y coordinate system for describing distances, with support point 21 at the origin of the system. Presume further the x axis to extend from support point 21 to support point 24 and components of a distance parallelling the x axis to be measured as a fraction of the distance between support points 21 and 24. Presume still further the y axis to extend from support point 21 to support point 22 and components of a distance parallelling the y axis to be measured as a fraction of the distance between support points 21 and 22. Expressions can then be written for the equilibria of moments about the y and x axes, respectively, as follows, where the force $\vec{F}_A$ is assumed to be applied at point x, y on touchplate 20.

$$(F_2\cdot 1) + (F_3\cdot 10 = F_A\cdot y \qquad (7)$$

$$(F_3\cdot 1) + (F_4\cdot 1) = F_A\cdot x \qquad (8)$$

Performing the scalar multiplications by unit scalar, 1, the moment arm of forces applied at support points in corners of touchplate 20 not on the axis around which moments are taken, the x, y coordinates at which $\vec{F}_A$ is applied can be calculated from the scalar amplitudes of its resolved component as follows:

$$x = (F_3+F_4)/(F_1+F_2+F_3+F_4) \qquad (9)$$

$$y = (F_2+F_3)/(F_1+F_2+F_3+F_4) \qquad (10)$$

In FIGURE 3 the mechanical member to be considered is a right rectangular prism 30 supported at support points 21, 22, 23 and 24 are assumed for the present to be weightless. (The rectangular parallelepiped or right rectangular prism is of interest since it is the shape of the cabinetry of many types of electronic equipment). If the touchpoints of concern were located solely on the top surface of the prism 30 and if user-applied force $\vec{F}_A$ were downward applied with no sideward component the determination of the x, y coordinates of point 31 at which force $\vec{F}_A$ is user-applied could be carried forward exactly as if the prism 30 were a touchplate 20 (despite its being a thick one). The problem is that a frontward or backward component of force applied by the user to the top surface of parallelepiped 30 generates a moment about the x axis owing to the height of the prism 130 in the z direction orthogonal to the x, y plane. This moment is considered zero in equation 7, based on the moment arm provided by the thickness of the touchplate 20 being considered negligibly small. Similarly, a leftward or rightward component of force applied by the user to the top surface of parallelepiped 30 generates a moment about the y axis, not taken into consideration in equation 8

owing to the moment arm provided by the thickness of the touchplate 20 being considered to be negligibly small.

Let $\vec{F}_A$, $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$, and $\vec{F}_4$ be resolved as follows $\vec{1}_x$, $\vec{1}_y$ and $\vec{1}_z$ are positive unit vectors in the x, y and z directions, respectively.

$$\vec{F}_A = (F_{A-x}\cdot\vec{1}_x) + (F_{A-y}\cdot\vec{1}_y) + (F_{A-z}\cdot\vec{1}_z) \quad (11)$$

$$\vec{F}_1 = (F_{1-x}\cdot\vec{1}_x) + (F_{1-y}\cdot\vec{1}_y) + (F_{1-z}\cdot\vec{1}_z) \quad (12)$$

$$\vec{F}_2 = (F_{2-x}\cdot\vec{1}_x) + (F_{2-y}\cdot\vec{1}_y) + (F_{2-z}\cdot\vec{1}_z) \quad (13)$$

$$\vec{F}_3 = (F_{3-x}\cdot\vec{1}_x) + (F_{3-y}\cdot\vec{1}_y) + (F_{3-z}\cdot\vec{1}_z) \quad (14)$$

$$\vec{F}_4 = (F_{4-x}\cdot\vec{1}_x) + (F_{4-y}\cdot\vec{1}_y) + (F_{4-z}\cdot\vec{1}_z) \quad (15)$$

Equations 6, 7, and 8 can then be rewritten in correct form for a rectangular prism with appreciable height in the z direction as follows:

$$F_{1-z} + F_{2-z} + F_{3-z} + F_{4-z} = F_{A-z} \quad (16)$$

$$(F_{2-z}\cdot 1) + (F_{3-z}\cdot 1) = F_{A-z}\cdot y) + (F_{A-y}\cdot 1) \quad (17)$$

$$(F_{3-z}\cdot 1) + (F_{4-z}\cdot 1) = F_{A-z}\cdot x) + (F_{A-z}\cdot 1) \quad (18)$$

It can be discerned from these equations that determining F_{A-y} and F_{A-x} as well as F_1, F_2, F_3 and F_4 is necessary to the calculations of the x and y coordinates. F_{A-y} and F_{A-x} can be determined by installing force sensors at support points 21, 22, 23, and 24 that determine not only F_{1-z}, F_{2-z}, F_{3-z}, and F_{4-z} — but F_{1-y} and F_{1-x}, F_{2-y} and F_{2-x}, F_{3-y} and F_{3-x}, and F_{4-y} and F_{4-x} as well. Then, the following equations 19, 20 based on prism 30 being restrained from leftward or rightward translation and forward or backward translation can be cross-solved with equations 16, 17, 18 to obtain the x and y coordinates of point 31 to which $\vec{F}_A$ is user-applied.

$$F_{1-y} + F_{2-y} + F_{3-y} + F_{4-y} = F_{A-y} \quad (19)$$

$$F_{1-x} + F_{2-x} + F_{3-x} + F_{4-x} = F_{A-x} \quad (20)$$

Certain structural arrangements are possible that allow simplified sensing of F_{A-y} with one force sensor and of F_{A-x} with one force sensor. For example, support points 21, 22, 23 and 24 may be on a platform underlying prism 30, and shear forces between the platform and the bottom surface of the parallelepiped may be measured to determine F_{A-x} and F_{A-y} directly. This will be dealt with in greater detail further on in the specification. Cross-solving equations 16—20 generates the following expressions for the x, y coordinates of point 31 to which the user applies force.

$$x = [F_{3-z}+F_{4-z}-(F_{1-x}+F_{2-x}+F_{3-x}+F_{4-x})]/(F_{1-z}+F_{2-z}+F_{3-z}+F_{4-z}) \quad (21)$$

$$y = [F_{2-z}+F_{3-z}-(F_{1-y}+F_{2-y}+F_{3-y}+F_{4-y})]/(F_{1-y}+F_{2-y}+F_{3-y}+F_{4-y}) \quad (22)$$

In FIGURE 4 the mechanical member to be considered is still a right rectangular prism 30, but the touchpoints of concern are considered to be on its front surface, as viewed from right of page, rather than on its top surface as in FIGURE 3. The sensors at support points 21, 22, 23 and 24 are still assumed to resolve support forces in each of the x, y and z directions The x and z coordinates of the point 32 of $\vec{F}_B$ are to be determined.

$$F_B = (F_{B-x}\cdot\vec{1}_x) + (F_{B-y}\cdot\vec{1}_y) + (F_{B-z}\cdot\vec{1}_z) \quad (23)$$

Equations 24, 25, 26, 27 and 28 are written presuming restraint of parallelepiped 30 to prevent translation in the y direction, rotation about the x axis, rotation about the y axis, translation in the x direction and translation in the z direction, respectively.

$$F_{1-y}+F_{2-y}+F_{3-y}+F_{4-y} = F_{B-y} \quad (24)$$

$$(F_{2-z}\cdot 1) + (F_{3-z}\cdot 1) = (F_{B-y}\cdot z) + (F_{B-z}\cdot 0) \quad (25)$$

$$(F_{3-z}\cdot 1) + (F_{4-z}\cdot 1) = (F_{B-x}\cdot z) + (F_{B-z}\cdot x) \qquad (26)$$

$$F_{1-x}+F_{2-x}+F_{3-x}+F_{4-x} = F_{B-x} \qquad (27)$$

$$F_{1-z}+F_{2-z}+F_{3-z}+F_{4-z} = F_{B-z} \qquad (28)$$

Cross-solution of these equations for the coordinates x, z of point 32 yields the following:

$$z = (F_{2-z}+F_{3-z})/(F_{1-y}+F_{2-y}+F_{3-y}+F_{4-y}) \qquad (29)$$

$$x = [F_{3-z}+F_{4-z}-z(F_{1-x}+F_{2-x}+F_{3-x}+F_{4-x})]/(F_{1-z}+F_{2-z}+F_{3-z}+F_{4-z}) \qquad (30)$$

Some thought will lead one to the conclusion that the touchpoints can be located on any of the sides of the prism 30 and the point of application can still be determined, though the calculations are reduced somewhat by choosing the origin of the Cartesian coordinate system at the corner of that side, rather than at a corner of the opposing side.

Touchpoint arrays may be placed on any number of the faces of the prism 30. While theoretically one could apply force to one of the faces in such way as to cause the force sensors at support points 21, 22, 23 and 24 to respond indistinguishably from force applied to another face, in practical circumstances the component of force normal to the touched surface will exceed the components of force along the surface. So an initial comparison of

$$F_{1-x}+F_{2-x}+F_{3-x}+F_{4-x},\ F_{1-y}+F_{2-y}+F_{3-y}+F_{4-y},$$

and

$$F_{1-z}+F_{2-z}+F_{3-z}+F_{4-z}$$

to determine the largest will determine which of the three pairs of opposing sides of prism 30 is being touched. The polarity of this largest sum force then resolves which of the opposing sides is the one being touched. This procedure can be appropriately simplified where not every one of the faces of prism 30 has a touchpoint array thereon.

There are many other mechanical members that can be considered in connection with practicing the invention. Touchplates supported at only three points can be used, but the calculation of point of touching is more complex than the case where four-point support is used. Certain mechanical members may exhibit ambiguities in resolving the point of touching. In an integral "bookshelf" structure, where there is only horizontal (x, y) resolution as to point of touching, there can be ambiguity as to which of the shelves is touched, for example. Such problems can usually be solved by using a plurality of mechanical members, rather than a single one, to aid resolving the point of touching. Continuing the "bookshelf" structure example, forces on the "shelves" could be sensed independently. Or the sensing system of the present invention may, of course, be used in combination with another sensing system to avoid ambiguities.

Thusfar, there has been no consideration of the problem of the touchbar 10, touchplate 20 or rectangular prism 30 having of itself weight acting as a bias force or having set upon it or applied to it some bias force such as the weight of another object. The systems thusfar discussed can be assumed to be linear systems where superposition of forces is applicable — that is, the force sensors respond linearly or substantially so to force applied to them. Accordingly, the calculations of point of touching described above can be carried forward on the differentials of force applied to the sensors during time of touching. The components support forces countervailing the user-applied force, which are of relatively fast changing "pulse" nature, can be separated from the components of the support forces which countervail bias forces and are of relatively slowly changing "dc" nature and; the former components are retained for purposes of calculating the coordinates of point of touching and the latter components are discarded.

Also, in certain systems for locating point-of-touch it is possible to arrange for weight to be directed orthogonally to the directions in which the force sensors sense force so the weight is not sensed. This is possible in touchbars and touchplates located in a vertical plane, by way of example.

Operating on the differential of applied force permits a touchbar or touchplate to be touched either on the surface it receives its support on or the opposing surface, so long as the touch is in the region between support points simply by taking the absolute values of the differential forces before proceeding with the computation of point of touching. Preservation of the polarity of differential force through the calculations can permit the calculation of points of touch outside the region between support points. One can detect "cantilevered" positions of touch on ends of a touchbar extending past a pair of points of support, for example. This type of calculating can be convenient, as well, in calculating point of touch on a square touchplate supported at only three of its corners.

FIGURE 5 shows a system for detecting which of ten touchpoints numbered zero through nine on a touchbar 40 has force applied to it by the user. The resolved components of this force as opposed by forces F_1 and F_2 are transmitted by means of plungers 41 and 42 running through guides 43 (shown in cross-section) to compress bladders 44 and 45 filled with a hydraulic fluid and supported by a baseplate 46 (shown in cross-section). To allow twisting of the touchbar respective to plungers 41 and 42 during application of vertical force, the coupling of touchbar 40 to plungers 41 and 42 should be flexible as provided by a plastic glue, a spring, a loose-fitting Teflon ball and socket, or the like. The pressures in bladders 44 and 45 are transmitted via tubes 47 and 48 respectively to pressure sensors 51 and 52. Pressure sensors 51 and 52 convert changes in applied pressures to changes in electric signals proportional to F_1 and to F_2, respectively.

Higher frequency electrical noise components in the pressure sensor 51 and 52 output signals are respectively smoothed away by the similar low-pass characteristics of wide-band amplifiers 53 and 54, which characteristics exhibit a roll-off frequency high enough to permit the passage of responses to changes in the value of the F_1 and F_2 forces. Pressure sensor 51 and 52 output signals also are supplied as input signals to narrow-band amplifiers 55 and 56. The similar low-pass characteristics of amplifiers 55 and 56 suppress responses to higher frequency electrical noise components and also responses to changes in the values of the F_1 and F_2 forces. The output responses of wide-band amplifier 53 and of narrow-band amplifier 55 are applied to non-inverting input connection and inverting input connection respectively of a differential-input amplifier 57. In consequence, an output signal from amplifier 57 is proportional, by a scaling factor, G, to changes in the force $\vec{F}_1$, the common-mode rejection of amplifier 57 suppressing response to the bias value of F_1.

The output responses of wide-band amplifiers 53 and 54 are summed in a summation network 58, and the output responses of narrow-band amplifiers 55 and 56 are summed in a summation network 59. These summed responses are applied to the non-inverting input connection and inverting input connection, respectively, of a differential-input amplifier 60 to cause amplifier 60 to produce an output signal proportional (by the scaling factor G) to the sum of changes in the forces $\vec{F}_1$ and $\vec{F}_2$.

A coring amplifier 61, which is a direct-coupled differential-input amplifier that performs a bottom clip of positive-value signal and a top-clip of negative-value signal, receives the output signal of amplifier 60 at its non-inverting connection and is arranged to respond with output signal only if this input signal exceeds a predetermined noise margin signal applied to its inverting input connection. The output signal of coring amplifier 61 is supplied to a peak detector 62 which senses when a signal has reached a point of inflection in the maximum sense to generate keying signals for directing sample-and-hold circuits 63 and 64 to sample the signals proportional to ΔF_1, (the change in F_1) and to sample the signal proportional to $\Delta(F_1+F_2)$, i.e., the change in (F_1+F_2). ΔF_1 and $\Delta(F_1+F_2)$ are then held until touchbar 40 is again touched with force sufficient to cause coring amplifier 61 to receive sufficient input from differential amplifier 60 to overcome the noise margin.

Held $\Delta(F_1+F_2)$ from sample-and-hold circuit 64 is supplied to a resistance-ladder voltage divider 65 that develops voltage values,

$$0,\ 0.1\Delta(F_1+F_2),\ 0.2\Delta(F_1+F_2),\ 0.3\Delta(F_1+F_2),$$

$$0.4\Delta(F_1+F_2),\ 0.5\Delta(F_1+F_2),\ 0.6\Delta(F_1+F_2),$$

$$0.7\Delta(F_1+F_2),\ 0.8\Delta(F_1+F_2),\ 0.9\Delta(F_1+F_2),\ \text{and}$$

$$\Delta(F_1+F_2)$$

that define the zone limits for window voltage comparators arranged in a zone comparator 66. The one of the ten window comparators in zone comparator 66 in whose window ΔF_1 falls supplies the indication of a respective one of the touchpoints on touchbar 40 having been touched to a coder 67 which typically encodes zone comparator 66 output as a four-bit binary-coded decimal output. Guard-bands may be introduced between the active zones of zone comparator 66 response, as known in the art, to reduce false indications caused by touching the touchbar 40 at points too close to the edges of the indicated touchpoints.

Touchbars operated in accordance with the invention may be arrayed in keyboards, of course. Such arrangements are attractive in reducing the number of mechanical parts in a keyboard. The sample-and-hold circuits of the circuits associated with the various touchbars may be multiplexed to use the same resistive ladder voltage divider and band comparator, with a single coder receptive of key signals and board comparator output generating coded outputs for the entire keyboard.

It is attractive to use sampled-data systems for computing the coordinates of touch points in accordance with the invention, the computation being suited to the capabilities of standard microprocessors — e.g. to one from the MCS—48 family available from Intel Corp., Santa Clara, California. The use of such sampled-data systems largely eliminates the need for matching amplifier

gains and filter responses to assure proportionality of the responses to F_1 and to F_2 or its sum with F_1. An example of such a system is one suitable for use in connection with an electronic chessboard where the piece to be moved is pushed down on the square it presently occupies and after being transported to its new square is pushed down again.

FIGURE 6 shows in exploded view the construction of the chessboard and force sensor assembly. The board pattern is on an electrically grounded metallic plate 70 which is the common top plate of four capacitor structures having respective bottom plates provided by square metallization areas 71, 72, 73 and 74 on the top surface of a printed circuit board 75. Plate 70 is separated from printed circuit board 75 at their corners by spiral-coil compression springs 76. Springs 76 are held in place by bolts 77 passing through holes in the corners of plate 70, through respective ones of springs 76, and through holes in printed board 75 lining up with those in plate 70. Locknuts 78 on the ends of bolts 77 hold springs 76 in compression to maintain constant upward force on plate 70 respective to printed circuit board 75. Damping material, not shown, surrounds the springs to keep the plate from bounding. (In fact, a spongy material, such as used for weather stripping doors, may be used to surround the perimeter of the plate 70 for replacing springs 76 altogether.) The square metallization areas in square array, are thus held in diagram under respective quadrants of the chessboard pattern on the square plate 70. Printed-circuit board plug connections 80 and 81 (shown in somewhat exaggerated scale in FIGURE 6) are connected by metallization to respective pairs of the square metallization areas 71—74. These plug connections also make available electric contact to two ground metallization areas 82 and 83 around the perimeter of the square array of metallization areas 71—74 on the printed circuit board, against which metallization areas 82 and 83 compression springs 76 press, and these springs if of electrically conductive material can provide a grounding connection to plate 70. Alternative to such grounding connection or additional to it, a pigtail connection 84 soldered at one end to plate 70 can be soldered to a land 85 on one of the ground metallization areas 82, 83.

The capacitance, C, between electrically grounded plate 70 and any of metallization areas 71—74 has value in accordance with the well-known equation following, where A is the area of the smaller capacitor plate, d is the average distance between the roughly parallel plates and ε_0 is the dielectric constant of space.

$$C = \varepsilon_0 A/d \qquad (31)$$

While these capacitances could be formed shrinking the size of the square metallization areas 71—74 so they are only under the corners of the chessboard, the metallization areas 71—74 have been expanded to underlie entire respective quadrants of the chessboard, in order to increase the sizes of the capacitances to the tens or hundreds of picofarads for the normal range of chessboard sizes Downward force on the surface of the chessboard — as resolved into forces F_1, F_2, F_3, and F_4, respectively, for its forward left, rearward right, and forward right quadrants — reduces the values of d_1, d_2, d_3, and d_4 for each of the capacitances C_1, C_2, C_3, and C_4, respectively, 26 associated with metallization areas 71, 72, 73, and 74. The changes Δd_1, Δd_2, Δd_3 in d may for the moment be considered proportional to $-\Delta F_1$, $-\Delta F_2$, $-\Delta F_3$, and $-\Delta F_4$, the changes in F_1, F_2, F_3 and F_4. Differentiating these various relationships as expressed in logarithmic form leads to the following equations describing or approximating actual operation.

$$\Delta C_1/C_1 = -\Delta d_1/d_1 = \Delta F_1/F_1 \qquad (32)$$

$$\Delta C_2/C_2 = -\Delta d_2/d_2 = \Delta F_2/F_2 \qquad (33)$$

$$\Delta C_3/C_3 = -\Delta d_3/d_3 = \Delta F_3/F_3 \qquad (34)$$

$$\Delta C_4/C_4 = -\Delta d_4/d_4 = \Delta F_4/F_4 \qquad (35)$$

In practice one may choose not to use linear-compression-with-force springs, because one wishes to compensate for non-linearity in the capacitance-force relationship, the design of appropriate compression springs being well-known within the state-of-the-art procedure.

FIGURE 7 shows how the capacitances can be measured simply and cheaply at the input of the microprocessor used to calculate the point at which the chessboard is touched by the player-held chess piece. C1, C2, C3, and C4 are the capacitors with electrically grounded plates provided by plate 70 of FIGURE 6 and with electric floating plates provided by metallization areas 71, 72, 73, and 74, respectively, of FIGURE 6. The floating plates of capacitors C1, C2, C3, and C4 connect directly to input pins IP1, IP2, IP3, and IP4 of a microprocessor μP, and they are connected to a positive operating voltage +V through resistors R1, R2, R3 and R4, respectively. The respective resistances R_1, R_2, R_3, and R_4 of resistors R1, R2, R3, and R4 are alike and of large value — e.g., 10 megohms. The voltage +V is sufficiently remote from ground that capacitors C1, C2, C3 and C4 can be charged in a reasonably short time to voltages exceeding the threshold voltages (T_T's) of n-channel field effect transistors Q11, Q21, Q31 and Q41.

Microprocessor μP is assumed to be of a type having the customary open drain bidirectional configurations as input stages following its input pins IP 1, IP2, IP3, and IP4. At prescribed clamping times the gates 91, 92, 93, and 94 of field effect transistors Q11, Q21, Q31 and Q41 are pulsed high to discharge from capacitors C1, C2, C3 and C4 the charges placed on them via bleeder resistors R1, R2, R3 and R4, respectively. After the clamping times the μP counts (by counting means not specifically shown) the time it takes for the recharging of the capacitor C1, C2, C3, or C4 associated with the gate of a selected one of grounded — source field effect transistors Q12, Q22, Q32, Q42 to charge back to a voltage exceeding the threshold voltage of that transistor. The reaching of threshold voltage at the gates of the selected one of Q12, Q22, Q32, and Q42 is sensed at its drain electrode 96, 97, 98, or 99, which drain electrode selectively connects to the counting circuitry of microprocessor μP. The flow of information through microprocessor μP in order to obtain binary-coded four-bit x coordinate and four-bit y coordinate of the touched point at output 100 will now be considered, with reference to the flow charts of FIGURES 8—13.

FIGURE 8 charts the main program flow through microprocessor μP of FIGURE 7. After START connection 101 an INITIALIZE process 102 is carried forward wherein registers for FAST AVERAGE, SLOW AVERAGE, PLUS DELTA signals receive initial entries. A MEASURE FORCES process 103 is then done wherein the resolved forces at the four corners of chessboard touchplate 70 are measured. The subroutine for this is shown in FIGURE 9 and will be explained in detail below.

The next process 104 in the FIGURE 8 chart is to COMPUTE FAST & SLOW AVERAGES. In this process running fast averages and running slow averages of samples of each of the four measured forces are computed as will be explained in detail below in connection with FIGURE 10, e.g., the running fast average of the samples of one of these measured forces may be the running average of the last two of the samples, and the running slow average may be the running average of the last 2^8 of the samples. These fast and slow averagings are analogous in the sampled-data-signal regime to relatively wide-band and relatively narrow-band low-pass filtering in the continuous-signal regime.

A TOTALIZE process 105 follows, wherein the sum of the four most recent running fast averages of the four measured forces are combined to provide a running FAST TOTAL signal, and wherein the sum of the four most recent running slow averages of the four measured forces are combined to provide a running SLOW TOTAL signal. In a COMPUTE DELTA FORCE process 106 a DELTA FORCE signal is generated responsive to the FAST TOTAL signal less the SLOW TOTAL signal, all less a NOISE MARGIN signal. This process completes the computation of the amount by which the differential of the total force applied to touchplate 70 exceeds a threshold. The NOISE MARGIN signal is the threshold level that determines the degree of coring done in computing DELTA FORCE signal.

A decision 107 follows, DELTA FORCE >0. A NO decision indicates lack of information as to user-applied force on touchplate 70, and the routine loops back to the MEASURE FORCES process 103. A YES decision indicates good probability of user-applied force on touchplate 70 and the positive value is retained as DELTA FORCE for comparison in decision 109 with the preceding retained value of DELTA FORCE to determine whether there be increase or decrease in DELTA FORCE. An INCREASE decision retains the update DELTA FORCE in process 111 as LAST VALUE for the next comparison in decision 109 and directs computation of x—y location of user-applied force in process 112.

A DECREASE decision retains the update DELTA FORCE in step 110 as LAST VALUE for the next comparison in decision 109, and the routine loops back to MEASURE FORCES process 103. The computation of the x—y location of user-applied force in process 112 will be described in detail in connection with FIGURES 11, 12, 13. Thereafter the x, y location of the point of user-applied touch to touchplate 70 will in process 113 be forwarded for display or other use, after which the routine loops back to MEASURE FORCES process 113.

Decision 107 supplies YES decision only if the applied force in short-term is appreciably greater than long-term applied force, which suppresses bias forces on chessboard touchplate 70 such as those attributable to its weight and the weight of the chess pieces setting on it. Decision 109 permits continuing re-computation of the x, y coordinates of user-applied force until the user begins to withdraw that force so that the final computation in the series is made with the largest possible values of measured force, minimizing errors from electrical noise. But initial computation of a new point of touch is made almost immediately, without the user having to wait for optimization of the calculation.

In certain embodiments of the invention it may be desirable to arrange that DELTA FORCE, the measure of user-applied force, be made available from computation process 106 for use together with computed touchpoint location in the DISPLAY OR OTHERWISE USE RESULT process 113. This would be desirable, for example, where touchplate 70, rather than being a chessboard, selectively controls the amplitude of signal supplied to an array of loudspeakers, for example. The processes leading up to and including calculation of DELTA FORCE have been described as being made in one polarity sense using unsigned arithmetic; by choosing an appropriately high bias force and carrying forth these processes using signed arithmetic, information as to the direction of user-applied force can be obtained from the sign of DELTA FORCE. Process 108 is then preceded by a TAKE ABSOLUTE VALUE process.

FIGURE 9 is a flow chart that details the outline for measuring forces responsive to the charging of capacitors C1, C2, C3 and C4 in processor 103. After ENTRY connection 121 SELECT FIRST OF THE FOUR CORNERS process 122 takes place. Process 123 DISCHARGE SELECTED CAPACITOR follows.

Assuming Q11, Q21, Q31, Q41 of FIGURE 7 to be n-channel FETs, this process can be implemented by driving their gates all positive respective to ground. Then process 124 BEGIN CHARGING SELECTED CAPACITOR takes place at an F=0 reference clock cycle. After a one clock cycle delay in incrementer process 125, CHARGED decision 126 takes place wherein the voltage on the selected one of the capacitors C1, C2, C3 and C4 is compared with a threshold level to see if it has attained this level. If a NO decision be made, this portion of the subroutine measuring the number of clock cycles required for the voltage across the selected capacitor loops back, with the selected capacitor being allowed to charge another clock cycle before decision 126 is again taken. When a YES decision is reached in decision 126, the previous value of F is indicative of the time the selected capacitor takes to charge, dependent on the capacitance of the selected capacitor which in turn depends on the closeness of spacing of the capacitor plates and thus the resolved force on one of the plates of the capacitor is stored in SAVE F process 127. Decision 128 ALL FOUR CORNERS DONE follows, EXIT connection 129 being reached only if a YES decision be made. A NO decision, on the other hand, directs that a SELECT NEXT CORNER process 130 be undertaken, causing the subroutine to loop back to process 123 to derive a value of F representative of measured force for the next selected one of capacitors C1, C2, C3 and C4.

FIGURE 10 is a flow chart that details the routine comprising step 104 of the main program flow chart of FIGURE 8. After ENTRY connection 131 a START WITH ONE CORNER process 132 is undertaken. In the ensuing process 133 the SLOW AVERAGE of measured force for the selected corner is computed by subtracting, from the previous value of this SLOW AVERAGE, its value as divided by 2^8 (as can be obtained by simple bit-place shifting) and by then adding the update value of measured force. Eight bits resolution is used in measuring F values, but sixteen bits resolution is maintained in computing SLOW AVERAGE to accommodate the division of SLOW AVERAGE by 2^8. In the INITIALIZE process 102 of the FIGURE 8 main program flow, an initial value of SLOW AVERAGE for each measured force value may be provided by the measured force value itself. After SLOW AVERAGE has been computed for one corner, ANOTHER CORNER decision 134 is reached where it is determined whether SLOW AVERAGE has been computed for each of the four corners. A YES decision causes PICK NEXT CORNER process 135 to be undertaken and the subroutine loops back to process 133 to calculate the SLOW AVERAGE for the next corner. A NO decision initiates FAST AVERAGE computations. Processes 136, 137 and 139 and decision 138 in these computations are analogous to processes 132, 133, and 135 and decision 134, respectively. Process 137 differs from process 133 in that the average is over a short term (2^1 samples) rather than a long term (2^8 samples). The previous value of FAST AVERAGE and update value of measured force are summed, and the sum is divided by two (as may be done by bit-place shift). When decision 138 makes a YES decision the values of SLOW AVERAGE and of FAST AVERAGE for each of the four corners have been computed and EXIT step connection 140 is reached.

FIGURE 11 is a flow chart of the routine for the COMPUTE X—Y LOCATION process 112 of the FIGURE 8 chart of main program flow. In ENTRY connection 141 of this routine entry is made with SLOW AVERAGE and FAST AVERAGE for the measured forces on each of four quadrants of touchplate 70. The acronyms SBL, SBR, STL and STR will be used to designate SLOW AVERAGE values for the bottom-left, bottom-right, top-left and top-right quadrants respectively of touchplate 70 as depicted in FIGURE 6; and the acronyms FBL, FBR, FTL, and FTR to designate respectively corresponding FAST AVERAGE values. In process 142 variable R2, the sum of differentials in force on the left half of touchplate 70 is calculated; and in step 143 variable R3, the sum of differentials in force on the right half of touchplate 70, is calculated. A CALL LOCATE connection 144 ensues to call the subroutine of FIGURE 12 which calculates the x coordinate of the point of user-applied force on touchplate 70 proceeding from R2, R3 variables generated in steps 142, 143 of the FIGURE 11 flow chart. This subroutine extrapolates the summed differential forces on the left and on the right of touchplate 70 from the middle of the quadrant capacitors to the left edge and to the right edge of touchplate 70, then in effect computes the quotient of the rightmost of these extrapolation by the sum of the leftmost and the rightmost extrapolations to obtain a variable R5 that corresponds to x. In process 145 of the FIGURE 11 routine R5 is saved as x.

Computation of the y coordinate of the point of user-applied force follows. In process 146 R2 is calculated to equal the sum of the differentials in force on the bottom half of the touchplate 70; and in process 147 R3 is calculated to equal the sum of the differentials in force on the top half of touchplate 70. A CALL LOCATE connection 148 causes the subroutine of FIGURE 12 to be followed, and in process 149 the resulting value of R5 is saved as y coordinate. With both x and y computed EXIT connection 150 advances the main program flow of FIGURE 8 to process 113.

FIGURE 12 is the flow chart of subroutine to calculate the location of applied force. When LOCATE connection 151 is called in the initial process 152 of the subroutine variable R5 is first set to zero. After this the theoretical support forces on the corners of touchplate 70 that are equivalent to the actual support forces resolved at the centers of capacitors 71—74 are computed.

FIGURE 13 shows the considerations in which this computation is based. R2 and R3 are the actual measured forces; R2′ and R3′, the theoretical forces. The cross-section 153 of touchplate 70 is either its cross-section along the x axis or along the y axis; and the tilt of the cross-section is due to user applied force, omitted from the figure for reasons of clarity. The 2l distances in the x or y direction to corners of touchplate 70 at the extremities of cross-section 153 are twice the l distances to the centers

of capacitors 71—74. R2 and R3 for the angle of tilt of cross-section 153 shown are R2—AV and AV—R3 larger and smaller respectively than their average AV, and they are applied at distance l from the center of cross-section 153. The same tilt of cross-section 153 could be achieved using forces R2′ and R3′ of respective amplitudes AV+2(R2—AV) and AV—2(AV—R3) applied at distance 2l from center of cross-section 153, R2′+R3′ equalling R2+R3.

Returning to FIGURE 12, in process 154 AV=(R2+R3)2 is computed. In process 155 a variable A (which is the difference of R2′ from AV in FIGURE 13) is computed as equalling (2×R2)—AV. decision 156 determines if the computed A be valid, in which case it should be zero or positive. If A be negative and thus invalid process 157 causes A to be zero-valued instead of its value from process 155, in process 158 wherein the corrected value of R2 (i.e., corresponding to R2′ of FIGURE 13) is computed to equal (A+R2)/2. Process 159, decision 160 and process 161 and 162 used to determine corrected valued R3 are analogous to process 155, decision 156 and processes 157 and 158 used to determine corrected value of R2.

In process 163 a count value COUNT is established that is the number of bits of precision that are to be in the binary fraction the x or y coordinate is to be expressed in. CALL WHERE process 164 calls the WHERE connection 171 of the FIGURE 14 subroutine and returns one bit at a time with R4. In process 165 the previously stored R5 is place-shifted to one bit more significance; and in process 164, R4 is added to provide updated R5 to one more bit of precision. In process 167 COUNT is decremented by unity and in COUNT=0? decision 168 whether the new value of COUNT equal zero or not is determined. If the decision be NO, the subroutine loops back to the CALL WHERE process 164; if the decision be YES, R5 is applied to RETURN connection 169.

FIGURE 14 is a flow chart of the subroutine to calculate each bit of the binary fraction specifying the x or y coordinate of the point to which the user applies force. FIGURE 15 shows the geometrical considerations underlying the algorithm used for calculation. Assume, for example, the x coordinate is the subject of calculation. Place R2, the combined differential forces on the lefthand portion of touchplate 70, on the right (or unity) end of a unit length beam and R3, the combined differential forces on the righthand portion of touchplate 70, on the left (or zero) end. Drawing the momentum triangles, as well known from elementary mechanics, their hypotenuses intersect at a point 170 which has an x coordinate x_0 corresponding to the point at which the user applies force. By comparing amplitudes of R2 and R3 one can find the most significant bit of the binary fraction describing this coordinate, a ZERO where R2 equals or exceeds R3, and a one where R3 exceeds R2.

Now, the most significant bit of fraction of the distance 0.1 x, is from x origin can be determined by comparing R3 to (R2—R3)/2. This is because the triangles with common vertices at 170 and side R3 and (R2—R3)/2 opposing their respective vertices are similar triangles, and their altitudes from R3 and (R2—R3)/2 to 170 will be in the same ratio as R3 and (R2—R3)/2. This second most significant bit of the x coordinate is determined to be a ONE where R3 exceeds (R2—R3)/2. The algorithm continues this moving the left and right vertical lines defining the basis of triangles with vertices at 170, and comparising their bases on those verticals to determine the ratio of their altitudes to define another bit of resolution in the binary fraction x_0. This algorithm is a division algorithm of sorts.

Returning to the flow chart of FIGURE 14, following WHERE connection 171 is a subtraction process 172 for determining A=R2—R3. In RESULT SIGN? decision 173 following, a NEGATIVE decision initiates process 174 where A is updated to equal —A/2, followed by R3 residual being set equal to A in process 175 and R4 being determined to be ONE in process 176 before RETURN connection 180. A POSITIVE decision on the other hand initiates process 177 where A is updated to equal A/2, followed by R2 residual being set equal to A in process 178 and R4 being determined to be ZERO in process 179 before RETURN connection 180.

FIGURE 16 is an embodiment of the invention wherein a television set in a rectangular-prismatic cabinet 200 is suspended in a hutch cabinet (not shown) by support wires 201, 202, 203, and 204. Support wires 201 and 202 at the front corners of the top of cabinet 200 connect to a support bar 205 running from left to right in the hutch cabinet above the rectangular opening left in the front of the hutch cabinet for viewing the television screen on the front of cabinet 200. Support wires 203 and 204 at the rear corners of the top of cabinet 200 connect to strain gages 206 and 207, supported in turn by a support bar 208 of equal height to support bar 205, but located at the back rather than the front of the hutch cabinet. A support bar 209 located slightly further back in the hutch cabinet and at a height slightly above the bottom of cabinet 200 has two further strain gages 211 and 212 mounted on it so spaced that respective front plates on them are contacted by roller-bearing casters 213 and 214 mounted on the bottom corners of the back of the cabinet 200.

The strain gages 206, 207, 211 and 212 are of the resistance-bridge type with their own electronic pre-amplifiers for supplying electric inputs to a microprocessor 215 for determining the location of viewer touch on the faceplate in front of the television viewing screen at the front of cabinet 200. The viewer touches the faceplate in playing video games displayed by the television set or in interacting in certain television-aided computer graphics operations. Microprocessor 215 is normally located on the chassis (not shown) for the game or other support electronics, which may be tucked into the space above cabinet 200 and below support bars 205, 208. Its output 216 comprises plural-bit outputs, half of which bits specify the x coordinate of the point at which the faceplate in the front of

cabinet 200 is touched, and the remainder of which specify the y coordinate.

Support wires 201, 202, 203, and 204 are a few inches long so strain gages 203 and 204 react solely to the forces associated with the bending moments of the rear corners of the cabinet 200 top respective to the axis through its front corners, which moments are generated by viewer's touching the television screen flaceplate. Strain gages 211 and 212 respond solely to the components of lateral shear forces transmitted to them in directions normal to their faceplates. Thus the number of force sensors required to locate the point at which the face of a rectangular prism is touched is reduced to four. Cheap frictionless support without problems of unrestrained cabinet movements is also a feature of this construction.

Insofar as locating the horizontal coordinate of viewer touch on the television screen faceplate is concerned, the calculation in microprocessor 215 proceeds the same way as for position along a touchbar. The support wires do not constraint transmission of the component of the force normal to the screen to strain gages 211 and 212, and the horizontal position is calculated by dividing the response to differential of force transmitted to one of the gages 211, 212 by the sum of both their response to differentials of the forces transmitted to them.

Insofar as locating the vertical coordinate of viewer touch on the telvision screen faceplate is concerned, the bending moment about the axis at top front edge of cabinet 200 owing to force $\vec{F}_4$ applied some distance y down on the faceplate of the viewing screen has a value F_Ay. This bending moment is countervailed by this bending moment F_0Z_0 in the support wires 203, 204, where in F_0 is the magnitude of the sum of the forces applied to them, and wherein Z_0 is the distance between the axis through support wire 201, 202 connections to the top of cabinet 200 and the axis through support wire 203, 204 connection to the top. The value of F_A is known by summing the output responses of strain gages 206 and 207. Dividing this into F_0 as determined by summing the output responses of strain gages 201 and 202, results in finding y in terms of its ratio to known dimension Y_0.

A still further reduction in the number of force sensors required is provided by measured F_0 with a single strain gage at a location midway between the locations of strain gages 206 and 207 it replaces. Support wires 203 and 204 are dispensed with, and a single support wire with connections to the replacement strain gage and to the top of cabinet 200 at a point midway between the connection points of support wires 203 and 204 it replaces. The problem arising in this arrangement is that care must be taken to avoid the replacement gage responding to bending moments about vertical axes. Responses of strain gages 206 and 207 to such bending moments in the FIGURE 16 arrangement as pictured tend to be of opposite sense and thus cancel each other out in their being summed to determine F_0.

Thusfar the touchbar and touchplate problems have been analyzed in terms of the mechanics of beams without restraint at their points of support. The present invention is extensible to touchbar and touchplate problems analyzable in terms of the mechanics of beams restrained at their points of support as well. An example of this is where the touchplate is the top of plastic television cabinet, where the top is restrained to be horizontal at its front, at its rear and at its sides. The restraint on the top is in terms of the upward forces through the cabinet front, rear and side walls and bending moments that keep the cabinet top horizontal. User-applied force can be resolved into opposing forces and moments. The theorems of the area moment methods of treating restrained beams, well-known to civil and mechanical engineers, can then be applied front-to-back and side-to-side using measurements from strain gages mounted on the undersurface of the cabinet top as the bases for calculations of the point to which the user applies force.

The force sensors used to resolve user-applied force for determining point of touching can in some systems be used for also determining the direction in which force is applied, for supplying further input into the user-responsive system.

In the claims which follow, the bias force may be zero-valued. "Parallelly supplied" with reference to binary numbers is to be interpreted liberally, to include binary numbers being supplied during the same cycle of calculation, even though the times those binary numbers are supplied may not be contemporaneous at any specific point in time.

CLAIMS

1. A method for determining the identity of any one location from among a multiplicity of locations on a surface of a mechanical member, which one location has been selected by a user; comprising the steps of:

using force-sensitive sensors, which are connected to said member to produce respective electric signals descriptive of components of the force applied at said selected location, and

calculating from the relative amplitudes of those electric signals the identity of the location at which force is applied.

2. The method set forth in claim 1 wherein said calculating step includes the step of

differentiating said electric signals with respect to time for suppressing responses to static forces on said mechanical structure, while preserving response to dynamic forces on said mechanical structure.

3. The method set forth in claim 2 wherein said step of differentiating said electric signals with respect to time comprises:

accumulating short-term averages of said electric signals;

accumulating relatively long-term averages of said electric signals; and

differentially combining said short-term and long-term averages.

4. The method as set forth in claim 2 wherein said step of differentiating said electric signals with respect to time comprises the substeps of:

recurrently sampling said electric signals;

accumulating relatively short-term averages of said signal samples;

accumulating relatively long-term averages of said electric signal samples; and

differentially combining said short-term and long-term averages.

5. A method as set forth in claim 2, 3 or 4 wherein said step of differentiating said electric signals with respect to time includes:

suppressing to zero value all responses to dynamic force responsive to their sum failing to exceed a threshold value.

6. A structural arrangement for practicing the method of claim 1, comprising:

a structural member to which is connected force sensitive sensors at respective support points;

said sensors sensing the respective components of total force applied at said selected location: and

determining means which computes from the magnitudes of respective signals, in substantially real time, the identity of the selected location at which the user applies force.

7. The structural arrangement as set forth in claim 6, wherein:

said determining means includes means for determining derivatives with respect to time of magnitudes of said electric signals, which represent respective components of total applied force; and

said determining means uses said derivatives in carrying out its computation, in order to suppress in the calculations the effects of static forces on said structural member.

8. The structural arrangement set forth in claim 6 or 7 wherein said determining means includes:

means for calculating in one spatial dimension a ratio having as a numerator the total of response to one or more of said sensed magnitudes and having as a denominator the total of response to a larger number of sensed magnitudes which responses to sensed magnitudes included in the numerator total also are included in the denominator total.

9. The structural arrangement set forth in claim 7, wherein said determining means includes:

means for determining the excess of said derivatives over a noise margin threshold;

means for determining the derivative of said excess with respect to time; and

means responsive to a change in the sense of derivative of said excess to validate or enable further computation of the identity of the selected location to which said user applies force.

10. The structural arrangement set forth in claim 6, wherein the determining means includes:

means for computing from the sum of the derivatives with respect to time of said signals representing component forces for the purpose of determining the amount of user-applied force.

11. A general input control for practicing the method of claim 1, which is to be mechanically actuated when a user selects, by applying force to any one of a multiplicity of points on a surface of a mechanical member; and which includes means for identifying the selected one of said points;

wherein:

said member is supported at a plurality of points against a combined force comprising: a bias force, which is unchanging except on a relatively long time scale, and any force applied by said user; and

said identifying means includes:

sensor means responsive to forces exerted at respective support points for producing electric signals representing respective components of said combined force; and

computing means responsive to the relative magnitudes of said electric signals for computing the identity of the selected one of said points.

12. A mechanically actuated general input control as set forth in claim 11 wherein said means for computing comprises:

means for recurrently sampling said respective signals;

means for determining relatively long term averages of the sum of all of said respective signals responsive to resolved components of said combined force and for determining relatively short term averages of the sum of all of those said respective signals; and

means responding to a short term average of the sum exceeding the sum of concurrent long term average of the sum and a noise margin for enabling or validating the remaining computation of the identity of a touchpoint to which force is applied.

13. The mechanically actuated general input control as set forth in claim 11, wherein said means for computing the identity of any of said selected points, to which force is applied, comprises:

means for recurrently sampling said electric signals;

means for determining relatively long term averages of the sum of all of said respective signals responsive to resolved components of said combined force and for determining relatively short term averages of the sum of all of those said respective signals;

means for obtaining the difference between the sum of the short term averages and the sum of the long term averages;

means responding to said difference exceeding a noise margin for enabling or validating the remaining computation of the identity of a touchpoint to which force is applied; and

means for using said difference as an indication of the magnitude of user applied force when said difference exceeds said noise margin.

14. The mechanically actuated general input control as set forth in claim 11, wherein said computing means comprises:

means for recurrently sampling said respective signals;

means for determining relatively long term average of each of said signals representing respective components of said combined force and for determining relatively short term averages of each of those said respective signals; and

means for subtracting those said relatively long term averages from corresponding ones of said relatively short term averages, in order to eliminate response to bias force present in respective signals which correspond to resolved components of said applied force.

15. A method of determining the location at which a force is applied to a member substantially as hereinbefore described with reference to figure 5, or to figures 6 to 15 or to figure 16.

16. An arrangement for determining the location at which a force is applied to a member substantially as hereinbefore described with reference to figure 5, or to figures 6 to 15 or to figure 16.

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